Virginia Tech ◆ ECE/CS 5565, Network Architecture and Protocols I ◆ Fall 2024

Project 1: Introduction to OMNeT++/INET and Wireshark

Updated 9/11/2024 (Added item for Wireshark screenshots to report outline)

Introduction

In this project, you will install and gain experience with both of the tools that we will use in this class for projects. These are:

- the OMNeT++ simulation package and the associated INET framework, and
- the Wireshark network protocol analyzer.

You will install OMNeT++/INET and use it to simulate and compare the performance of two small Ethernet networks, one with an Ethernet switch and the other with an Ethernet hub. You will then install Wireshark and use it to examine the results from OMNeT++/INET at the frame level. In future projects, you will use OMNeT++/INET for more rigorous simulation studies and you will use Wireshark to analyze real-world network traffic.

Your work on this project consists of three phases: (1) install and use OMNeT++ and INET; (2) install and use Wireshark; and (3) submit a project report covering your work with both OMNeT++/INET and Wireshark.

Before starting on the project, read through this assignment to know how work in different phases fits together. Also, review the class syllabus especially sections on “Assessments,” “Grading,” “Late and Missed Work,” “Grading Questions," and “Graduate Academic Integrity.”

Phase 1: Simulation with OMNeT++ and INET

Complete the following steps for Phase 1 of the project.

1) Download and install the OMNeT++ discrete event simulator from https://omnetpp.org/. See the “Download” button on the front page of the website. There are versions of OMNeT++ for Windows, MacOS, and Linux. You will want to install the latest release, OMNeT++ 6.0.3, including the simulation environment and IDE.

2) OMNeT++ is a general-purpose discrete-event simulator that can be used to simulate many types of systems. The INET framework is an add-on to OMNeT++ to make it easier to simulate networks. It includes modules for OMNeT++ that can then be composed to build networks. Install the INET framework using the information provided at https://inet.omnetpp.org/. Click on the “Documentation” menu near the top of the front page and select “Installing INET” for information. Note that OMNeT++ should be properly installed before attempting to install the INET framework. You can learn more about OMNeT++ and INET at the respective websites and there are tutorials on YouTube. It is recommended that you focus your learning on OMNeT++ using the INET library rather than just OMNeT++ by itself.

3) Work through a few examples with the INET framework to gain some familiarity with OMNeT++/INET and to ensure that your installations of OMNeT++ and INET are working properly. It may be helpful to follow along with the “Getting Started with INET | OMNeT++ Tutorial” on YouTube (https://youtu.be/ujQ_jaItx_Y).

4) **Simulation with Ethernet Switch:** Follow along with the "OMNeT++ and INET Demo" video from the class Canvas site that is linked from the project assignment to build an OMNeT++/INET model for the small Ethernet network shown in Figure 1. The initialization file, omnetpp.ini, is also provided in a zip file with the project assignment. This network uses an Ethernet switch to connect two clients and two servers. Being an Ethernet switch, there is no contention on the Ethernet links. Save an image of the graphical view of the network to include in the report. An image can be saved from the OMNeT++ IDE.

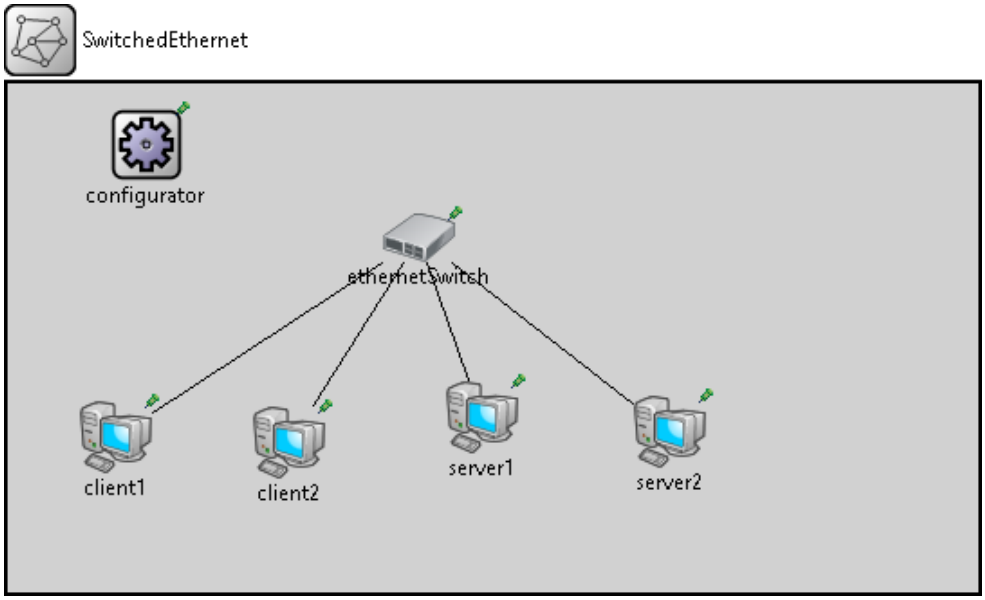

Figure 1. Simple network in the OMNeT++ Integrated Development Environment (IDE).

In the *.ini file, be sure that the length of the simulation time, `sim-time-limit`, is 80 seconds. Then, build the project and run the simulation. Do the following when the simulation completes.

a. Record the mean and standard deviation for end-to-end delay for Client1. You will include these values in a table in your report. Seeing these values was demonstrated in the video.

b. Create a histogram of end-to-end delay for Client1 and save an image of the histogram for inclusion in your report. Creating the histogram was demonstrated in the video. Note that there is a button in the IDE above the chart to save the image.

c. Be sure to save the client1.pcapng file for use in Phase 2 of this project. It is recommended to change the file name to indicate that it is associated with results for the Ethernet switch.

5) **Simulation with Ethernet Hub:** You will now examine performance for the same four hosts and applications by using an Ethernet hub instead of an Ethernet switch. The Ethernet hub simply acts as a physical level junction for the different Ethernet connections. Thus, there will be contention on the links. Also, the links are half-duplex (transmission in one direction at a time) rather than full duplex (transmission in both directions at once) as with the Ethernet switch.

Copy the OMNeT++ project for the switched Ethernet network to create a new project with a new name. To do this, right click on the top-level project folder and select "Copy." Then, right click at the very top folder and select paste "Paste." The paste operation will request a new name for the

project. Before making any edits to the *.ned file and the *.ini file, be sure that you are changing files in the new project and not the switched Ethernet project.

With the graphical editor, modify the network description (in the *.ned file) by replacing the Ethernet switch with an Ethernet hub. This will require deleting the switch, adding the hub, and reconnecting the four hosts to the hub. Also, rename the network to something meaningful.

With the source editor, update the connections in the *.ned file so that the four host connections are of the form `client1.ethg++`. The hub side of the connections should be kept as `ethernetHub.ethg++`. Also, remove `inet.node.ethernet.EthernetSwitch` reference near the top of the *.ned file. Save an image of the graphical view of the network with the Ethernet hub to include in the report.

In the *.ini file, update the name of the network to match the name in the *.ned file. By default, INET uses contention-free and full-duplex links in models for Ethernet. This is appropriate for a switched Ethernet configuration, but not for an Ethernet hub. The following two lines need to be included in the *.ini file to make all Ethernet links use CSMA/CD operation and to be half duplex.

```
**.eth[*].typename="EthernetInterface"
**.eth[*].duplexMode = false
```

The beginning "**" results in the parameters being applied to the Ethernet connections for all modules with such gates. These lines are included, but commented out, in the omnetpp.ini file provided with the project assignment. You can uncomment the two lines to model contention-based, half-duplex Ethernet connections for the network with the Ethernet hub. Ensure that `sim-time-limit` is set to 80 seconds in the *.ini file.

Build the project and run the simulation. It is recommended to start with animations to ensure that operation begins as expected and to then switch to express mode simulation. Do the following when the simulation completes.

a. Record the mean and standard deviation for end-to-end delay for Client1. You will include these values in a table in your report.

b. Create a histogram of end-to-end delay for Client1 and save an image of the histogram for inclusion in your report.

c. Be sure to save the client1.pcapng file for use in Phase 2 of this project. It is recommended to change the name to indicate that it is associated with the results with the Ethernet hub.

This completes Phase 1 of the project. You will report your results as described in Phase 3.

Phase 2: Analysis with Wireshark

Complete the following steps for Phase 2 of the project.

1) Download and install the Wireshark network analyzer from https://wireshark.org/. There are versions for Windows, MacOS, and Linux. The Wireshark site includes documentation and tutorials as well as files for downloading. You can also find tutorials on LinkedIn Learning (access with your Virginia Tech account) and YouTube.

2) **Analysis of Network with Ethernet Switch:** Open the *.pcapng file associated with the network with the Ethernet switch. You should see something similar to what is shown in Figure 2. Make a

screen shot of the Wireshark window to include in the report. Use Wireshark and the information in the *.pcapng file to determine answers to the following questions.

a. What Ethernet are addresses used for Client1, Client2, Server1, and Server2? This may require (straight-forward) speculation for some of the hosts.

b. What IP addresses are used for Client1, Client2, Server1, and Server2? This may, also, require speculation for some of the hosts.

c. What is the purpose of Frames 1, 2 and 3? What protocol is in use? Be concise.

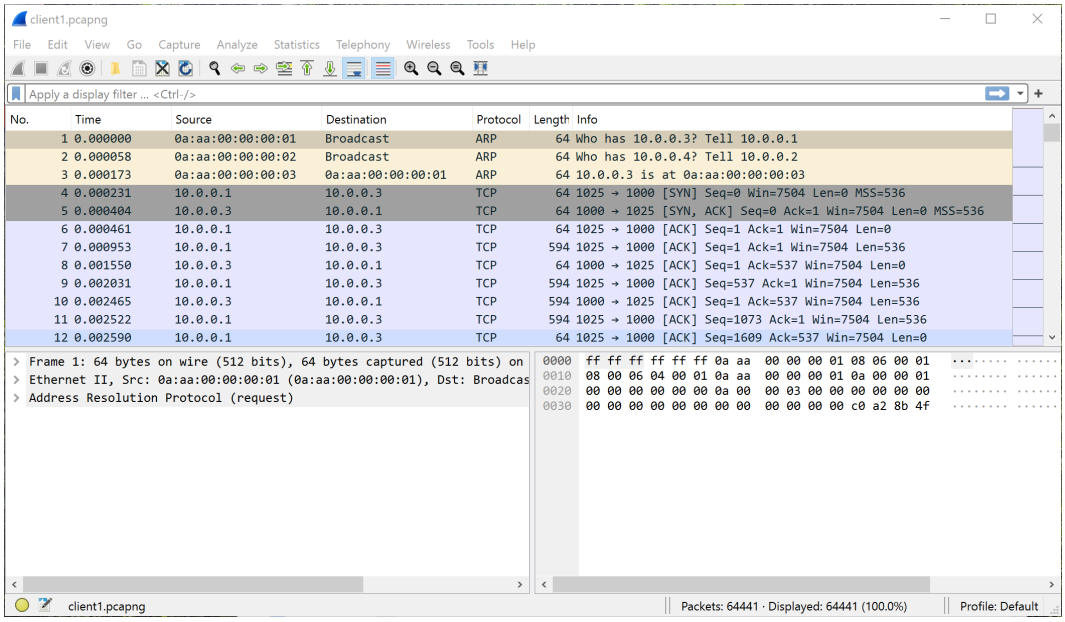

Figure 2. Captured Ethernet frames from OMNeT++/INET simulation shown in Wireshark.

d. What is the purpose of Frames 4, 5, and 6? What protocol is in use? Be concise.

e. Which frame carries the first block of data (not just control information) from Client1 to Server1? At what time is this frame recorded?

f. Which frame carries the last block of data (not just control information) from Server1 to Client1? At what time is this frame recorded?

g. Consider the frame that carries the last block of data from Server1 to Client1, as indicated in item f above. What are the source and destination Ethernet addresses for the frame? What are the source and destination IP addresses for the frame? What are the source and destination port numbers for the frame?

h. Consider the same frame as in item g above. Draw a diagram of the frame showing Ethernet header and trailer, IP header, TCP header, and the TCP payload. You do not need to show fields within the headers or the Ethernet trailer. Indicate the number of bytes in each header, the Ethernet trailer, and in the TCP payload.

i. Use the Statistics > Conversations menu in Wireshark to open a window showing various conversations in the captured packets. Select the Ethernet tab. Examine the conversation between Client1 and Server1, not considering broadcast frames. How many bytes were

transferred from Client1 to Server1 (this will include header bytes)? What was the duration of the conversation? What is the effective bit rate from Client1 to Server1?

3) **Analysis of Network with Ethernet Hub:** Open the *.pcapng file associated with the network with the Ethernet hub. Make a screenshot of the Wireshark window. Use Wireshark and the information in the *.pcapng file to determine answers to the following questions.

   a. Which frame carries the first block of data (not just control information) from Client1 to Server1? At what time is this frame recorded?

   b. Which frame carries the last block of data (not just control information) from Server1 to Client1? At what time is this frame recorded?

   c. Use the Statistics > Conversations menu to open a window showing the conversations. Select the Ethernet tab. Examine the conversation between Client1 and Server1, not considering broadcast frames. How many bytes were transferred from Client1 to Server1 (this will include header bytes)? What was the duration of the conversation? What is the effective bit rate from Client1 to Server1?

This completes Phase 2 of the project. You will report results as described in Phase 3.

Phase 3: Submission of Report

You are to create a written report with the content described below. Your full name, Virginia Tech PID, Virginia Tech email address, and assignment name ("ECE/CS 5565 Project I") should appear at the top of the first page. Do *not* include your Student ID number.

Distinct numbered section headings should be used to indicate your response to the items indicated below. Present your answers as specified in the outline below. All answers should be concise and clear. Your report should be submitted as a single PDF file with the following file name: *YourLastName_YourFirstName*_P1.pdf. Note that "YourLastName" is your last or family name as used by Virginia Tech and that "YourFirstName" is your first or given name as used by Virginia Tech. Submit the report in the Assignments section of the class Canvas site by the due date.

Use the following outline for your report. Include section numbers and headings in your report.

1. Network Simulation
   - 1.1. Network Images – Include an image of each of the two networks simulated.
   - 1.2. Table of Numerical Results – Include a table show the mean and standard deviation of end-to-end delay, as reported in OMNeT++/INET, for the network with the Ethernet switch and the network with the Ethernet hub. Do not include a screen shot of the results.
   - 1.3. Histograms – Include images of both histograms, with each clearly labeled.
   - 1.4. Comparison – Discuss how the results (numerical results and histograms) differ for the two networks. Explain the reason for these differences. Be concise, but specific. Explain the reason for these differences. Be concise, but specific. Refer to specific results and refer to specific features of how the two networks operate.
   - 1.5. Discussion – Briefly discuss any problems that you experienced with the simulation portion of the assignment.
2. Wireshark Analysis
   - 2.1. Images of Wireshark Windows – Include the screenshots of the main Wireshark window for both networks
   - 2.2. Questions for Network with Ethernet Switch – Answer questions (a) through (i) from step 2 of Phase 2.

2.3. Questions for Network with Ethernet Hub – Answer questions (a) through (c) from step 3 of Phase 2.

2.4. Comparison – Discuss how the results for the Ethernet conversation statistics (question i under 2.1 and question c under 2.2) differ. Explain the reason for these differences. Be concise, but specific. Refer to specific results and refer to specific features of how the two networks operate.

2.5. Discussion – Briefly discuss any problems you experienced with the Wireshark portion of the assignment.

Honor System Expectations

Your work on this project and your submission should be your own. You may consult with others about how to install and use OMNeT++/INET and Wireshark. You are encouraged to ask such questions and provide responses to such questions using the "Project 1" topic in the Discussions section of the class Canvas site. **You are not to collaborate with others on the actual creation of the simulation models and running the simulations required for the project, analyzing results, providing the information for the report, or on writing the report. Such collaboration will be considered a violation of Virginia Tech's Graduate Honor Code.** Please review the section on "Graduate Academic Integrity" in the course syllabus available on the class Canvas site before you begin work on this project.

Grading Rubric

Your project will be graded using the following rubric as a guide. The maximum score is 100 points.

Project Criterion	Attributes of Strong Work	Attributes of Medium Work	Attributes of Weak Work	Maximum Points
Network images (1.1)	Images of both networks are included and they are correct and legible. (6 points)	Both images are included, but there are small issues with correctness or legibility. (4-5 points)	One or more images are missing and/or there are significant problems with the images (0-3 points)	6
Table of numerical results (1.2)	All data is included, all values are correct, all table headings are appropriate, and table is clear. (10-12 points)	There is a single omission, data is incorrect, or the table is not fully labeled. (6-9 points)	There are multiple omissions or other errors. The table is not clear. (0-5 points)	12
Histograms (1.3)	Both histograms are included and correctly labeled. Results are appropriate for both histograms. (10-12 points)	Both histograms are included, but results in one are not reasonable. Labeling is not clear. (6-9 points)	One or both histograms are missing. Results not reasonable. Images are not labeled. (0-5 points)	12
Comparison of simulation results (1.4)	Key differences are clearly indicated. Differences cited are consistent with and refer to numerical results and the histograms. Reasons for differences are given and are reasonable. Reasons point to specific differences in the networks and their operation. (10-12 points)	There is some lack of clarity or specificity in the key differences. Some differences are stated without reference to specific observations. Reasons for differences are not completely clear or are not specific. Some reasons are stated without reference to the networks and their operation. (6-9 points)	Differences are incomplete, general, and/or vague. Differences cited mostly do not reference specific observations. Reasons for differences are incomplete, general, and/or vague. Reasons mostly do not refer to the networks and their operation. (0-5 points)	12

Project Criterion	Attributes of Strong Work	Attributes of Medium Work	Attributes of Weak Work	Maximum Points
Discussion of simulation work (1.5)	Section is included with reasonable content, even if just a statement that no problems were encountered. (3 points)	Section is included, but statement is not clear or incorrect. (1-2 points)	Section is not included. (0 points)	3
Images of Wireshark windows (2.1)	Images of the Wireshark window for both networks are included and they are reasonable and legible. (4 points)	Both images are included, but there are small issues with correctness or legibility. (2-3 points)	One or more images are missing and/or there are significant problems with the images (0-1 points)	4
Questions for Wireshark analysis of switched network (2.2)	All or almost all of questions a through i are answered correctly. Answers are specific. (17-20 points)	Most of the questions are answered correctly, but there are several mistakes or partially incorrect answers. Some answers are vague. (10-18 points)	All or many of the questions are answered incorrectly or are missing. Many answers are vague. (0-9 points)	20
Questions for Wireshark analysis of hub network (2.3)	All or almost all of questions a through c are answered correctly. Answers are specific. (7-8 points)	Most of the questions are answered correctly, but there are a few mistakes or partially incorrect answers. A few answers are vague. (4-6 points)	All or many of the questions are answered incorrectly or are missing. Many answers are vague. (0-3 points)	8
Comparison of Wireshark analysis (2.4)	Key differences are clearly indicated. Differences cited are consistent with and refer to conversation information from Wireshark. Reasons for differences are given and are reasonable. Reasons point to specific differences in the networks and their operation. (12-14 points)	There is some lack of clarity or specificity in the key differences. Some differences are stated without reference to specific observations. Reasons for differences are not completely clear or are not specific. Some reasons are stated without reference to the networks and their operation. (8-11 points)	Differences are incomplete, general, and/or vague. Differences cited mostly do not reference specific observations. Reasons for differences are incomplete, general, and/or vague. Reasons mostly do not refer to the networks and their operation. (0-7 points)	10
Discussion of Wireshark work (2.5)	Section is included with reasonable content, even if just a statement that no problems were encountered. (3 points)	Section is included, but statement is not clear or incorrect. (1-2 points)	Section is not included. (0 points)	3
Overall presentation and submission	Work is clearly presented and organized with headings in the correct order. Text, tables, and images are clear and clearly labeled. Followed submission instructions. (9-10 points)	Work is mostly clear but with some lack of clarity in writing, images, and/or tables. Organization is adequate, but not completely aligned with directions given. (6-8 points)	Work is hard to follow. Did not follow instructions for organizing the report. Did not fully follow submission instructions. (0-5 points)	10
TOTAL POINTS				100

Key References

- OMNeT++ Discrete Event Simulator: https://omnetpp.org/
- INET Framework: https://inet.omnetpp.org/
- "Getting Started with INET | OMNeT++ Tutorial" on YouTube: https://youtu.be/ujQ_jaItx_Y
- Wireshark Network Protocol Analyzer: https://www.wireshark.org/